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Designing for Future Building: Adaptive Reuse as a Strategy for Carbon Neutral Cities

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Abstract: Adapting existing buildings is a viable alternative to demolition and replacement in order to mitigate climate change and global warming. Australian cities with inherent cultural heritage fabric, like Melbourne and Sydney, are actively promoting building adaptive reuse as a strategy that supports their programme for developing carbon-neutral cities. Thus, designing for future buildings with embedded adaptive reuse potential is a useful criterion for sustainability. Building adaptive reuse entails less energy and waste, protects the buildings' heritage values- its socio-cultural and historic meanings; while giving them a new lease of life. This paper looks into urban conservation-- an interdisciplinary field that combines adaptive reuse, architecture and community development of the built heritage. It will further introduce the development of a new rating tool known as adaptSTAR, suitable for assessing the adaptive reuse potential of future buildings to lead and help promote the development of low to no carbon built environments.

Keywords: Adaptive Reuse, Sustainability, Climate Change, Architecture, Urban Conservation

Introduction

RODWELL [1] SUGGESTS that to achieve a sustainable world, initiatives must start with the city, since cities are the focus of consumption and degradation in the natural environment. He further declares that the goal of sustainability in a city is the reduction of its use of non-renewable natural resources and production of wastes whilst simultaneously improving its liveability. Moreover, the built environment is the major contributor to global greenhouse gas emissions (GGE), where 45 percent of carbon dioxide emissions can be directly or indirectly connected to construction and building operation [2]. The demand for energy, land and materials resulting from new developments needs to be tempered with taking better care of existing buildings, extending their life expectancy and using less energy. According to Balaras et al. [3], the existing stock has the greatest potential to lower the environmental load of the built environment significantly within the next 20 or 30 years. This urges building professionals to produce more energy-efficient buildings and renovate existing stocks according to modern sustainability criteria [4]. Existing buildings that have been upgraded to achieve substantial cuts in GGE are considered a more climate-friendly strategy than producing new energy efficient buildings [5].

Conservation principles and sustainability plays a vital role in promoting energy efficiency improvements in existing buildings (both heritage listed and non-listed), as indicative in the practice of adaptively reusing old buildings of different types as seen successfully around the world [6-8]. Making better use of existing buildings is a major contribution to climate

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change adaptation and encourages "a culture of reuse" where the impacts of a changing climate can be minimized as much as practicable. Building adaptive reuse has a major role to play in the sustainable development of communities, limiting potential demolition and reconstruction wastes [6]. It also provides benefits of conserving green space, improving the microclimate air quality, and maintaining habitat, ecosystem and water quality [9]. Building adaptive reuse is defined as "a significant change to an existing building function when the former function has become obsolete" [10].

The purpose of this paper is to outline the need and the philosophy for an adaptive reuse rating tool targeted to new design of buildings to support embedded adaptive reuse potential which will help promote low to no carbon built environments, and describe the approach taken by the researchers to develop and validate it. Contemporary literature pertaining to urban conservation, adaptive reuse, sustainability and architecture is reviewed and forms the basis for a proposed conceptual framework and detailed methodological approach. The paper concludes with some initial observations from the twelve (12) selected successful case studies in New South Wales and Melbourne, Australia; with emphasis on the redevelopment of Prince Henry Hospital at Little Bay, Sydney, Australia.

Urban Conservation and Sustainability

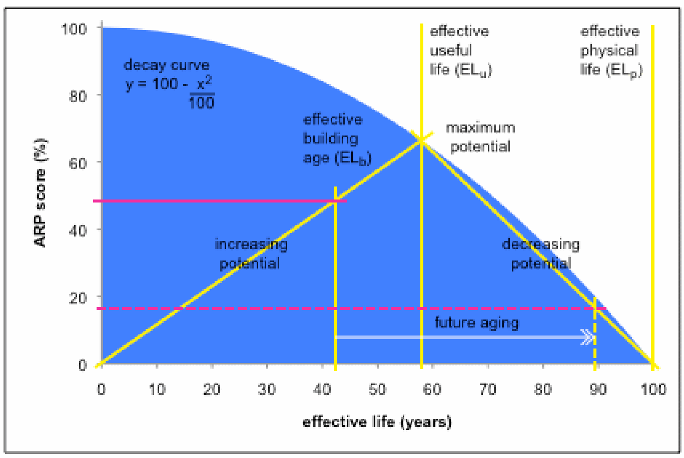
Urban conservation is a concept introduced in the 1960s which focuses on the management of change in historic cities; it is the blending of both existing and new developments and is a process of maintaining the character of a historic quarter while serving its present day communities and their needs. It involves cultural continuity and the gradual adaptation of the urban environment, which is a political, economic and social concern [1; 11- 12]. Rodwell [1] defines sustainability as "a means to provide a safe healthy comfortable and indoor environment while limiting the impact on the earth's natural resources". He also asserts that minimum intervention is a principle shared by both conservation and sustainability. Further, he points out that the reduce, recycle and reuse of non-renewable resource and waste management form an essential part of the coincidence between conservation and sustainability. In addition, Orbasli [12] notably demonstrates that the sustainability of built heritage not only retains the inherent character and respects historic buildings as an intrinsic part of the built environment, but also contribute to the economy of cities.

Adaptive Reuse and Sustainability

The United Nations Environment Programme [13], identified the United States, Australia and Canada as the top three countries with the largest carbon dioxide emissions from buildings per capita. Yudelson [14] claims that about 75% of all buildings expected to be operating in the year 2040 are already built or renovated. He also mentioned that the pace of building energy retrofits and green upgrades will accelerate dramatically in the next five years due to the fact that there are nearly 5 million existing buildings in the US and Canada that are ripe for retrofit into energy-efficient structures. Further, the Urban Land Institute [15] indicates that new construction accounts for merely 1 to 1.5 % of existing building stock each year in most developed countries. Thus, adaptive reuse or retrofitting plays such a critical role in reducing emissions from the built environment. UNEP [2] emphasizes that adapting and retrofitting of existing buildings to the optimal energy efficiency standard must be given more focus by the building sector. Gorse and Highfield [16] assert that there is no better example of the environmental benefits of effective sustainability in practice than the recycling of buildings. In addition, the reuse of materials and assemblies salvaged from the building being adaptively reused or other buildings is a positive sustainable choice.

Adaptive Reuse Potential (ARP) Model

Until now experience and intuition are often the only guides to making decisions for adaptive reuse [16]. However, through the ARP model [8] existing buildings can now be ranked on their adaptive reuse potential at any point in time. The useful (effective) life of a building or other asset in the past has been particularly difficult to forecast because of premature obsolescence [17]. In the ARP model, the seven obsolescence categories are based on Seeley [17] and are listed as physical, economic, functional, technological, social, legal and political. The ARP model predicts useful life as a function of (discounted) physical life and obsolescence, and allows the calculation of the adaptive reuse potential of a building's life cycle so that the right timing for intervention can be applied. The ARP model, summarized in Figure 1, was firstly demonstrated by using a case study in Hong Kong [18].



$$\text{ARP (increasing)} = \frac{\left(100 - \frac{EL_u^2}{100}\right) \cdot EL_b}{EL_u} \qquad \text{ARP (decreasing)} = \frac{100 - \frac{EL_u^2}{100}}{100 - EL_u} \cdot (100 - EL_b)$$

Fig. 1: Adaptive Reuse Potential Model [19]

The model has generic application to all countries and all building typologies. It requires an estimate of the expected physical life of the building and the current age of the building, both reported in years. It also requires an assessment of physical, economic, functional, technological, social, legal and political obsolescence, which is undertaken using surrogate estimation techniques as no direct market evidence exists. The ARP model has been widely published and is considered robust as it has been tested in hindsight against 64 adaptive reuse projects globally [19] and recently validated by a new multi criteria decision analysis tool called iconCUR [20; 21].

The decay curve can be reset by strategic capital investment during a renewal process by the current owner, or a future developer, at key intervals during a building's life cycle. ARP scores in excess of 50% have high adaptive reuse potential, scores between 20% and 50% have moderate potential, and scores below 20% have low value, representing about one-third of the area under the decay curve in each case. Potential means that there is a propensity for projects to realize economic, social and environmental benefits when adaptive reuse is implemented. ARP is conceptualized as rising from zero to its maximum score at the point of its useful life, and then falling back to zero as it approaches physical life. Where the current building age is close to and less than the useful life, the model identifies that planning activities should commence.

Research Methodology

The aim of this research is to create and validate a design evaluation tool that will lead to making purposeful design decisions for future adaptive reuse at the time they are designed, or put simply, planning for reuse as a key design criterion. As a proven indicator for identifying the potential for adaptive reuse in existing building stock, this research will use the ARP model [19] to validate a new design rating tool called adaptSTAR, which is a weighted checklist of design strategies that lead to future successful adaptive reuse of buildings. The development and testing of this checklist is the focus for this research. The main deliverable of the research is the creation and validation of the new adaptSTAR model, which is essentially a weighted checklist of design decisions that lead to best practice outcomes. It is similar in concept to the Green Building Council's Green Star or LEED methodology where performance is assessed using a standard five-star rating scheme. The methodological approach of this research study is essentially in three parts and relates closely to the planned three years of the project (see Figure 2).

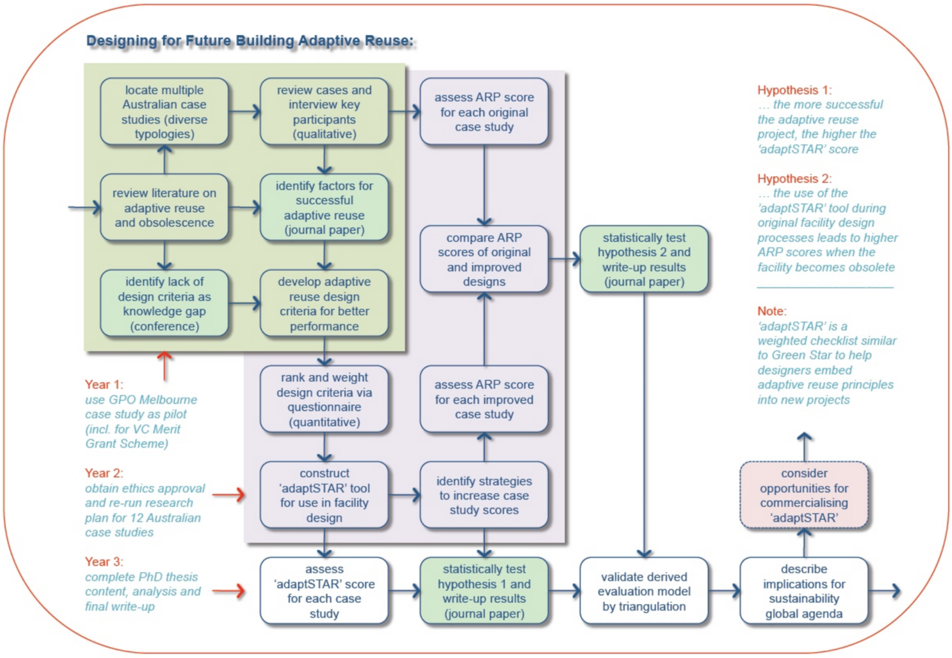


Fig.2: Research Plan Logic

This research uses a sequential mixed mode methodology (qualitative and quantitative), where the first stage explores 12 successfully completed Australian adaptive reuse projects to understand, with hindsight, what factors (related to the project's original design) led to its adaptive reuse transformation. This step involves a detailed case study of each project supported by expert opinion from key stakeholders, including the architectural team, structural engineer, services engineer, quantity surveyor and facilities manager (as applicable). The case studies represent quite different building typologies. Given each case study will also have different latent characteristics, the list of factors is likely to be reasonably diverse. The assembly of these factors forms the base criteria to be used and scored in the adaptSTAR model. Factors will be collated into groups representing physical, economic, functional, technological, social, legal and political categories.

The second stage takes this list of factors and assigns weights to them. This is achieved by an online questionnaire to the Australian architectural profession seeking the level of importance of each factor (via a 5-point Likert scale). It is unlikely that all factors are of equal importance. Some factors of low importance will be discarded. These judgements are independent of the 12 case studies and so the approach is not merely self-serving.

The third stage evaluates the performance of the derived model in a number of ways. The relationship between adaptSTAR and the ARP model [19] is tested to determine if the respective scores are correlated. From the data discovered through the previous stages, a weighted list of design criteria is constructed. The ARP model assumes the seven obsolescence categories are equally weighted, and so too does this research. However, for each obsolescence category, design strategies are weighted directly from the discovered Likert scores. Points are used to define a user-friendly star rating scheme similar to that used currently in green building evaluation. Each of the twelve case studies is assessed using adaptSTAR (to determine their performance) and the ARP model (to determine their potential at the time of their redevelopment). The hypotheses for the research are:

H1: The more successful the adaptive reuse project, the higher the adaptSTAR score
H2:The use of the adaptSTAR tool during original facility design processes leads to higher ARP scores when the facility becomes obsolete.

Initial Development of the adaptSTAR Model

This research study involves 12 successfully completed award-winning Australian adaptive reuse case studies that are real life projects and demonstrate the successful blending of modern technology and design while respecting the building's historic character. They showcase rich and diverse architectural solutions in terms of conserving and adapting existing buildings to sustainable new uses. The selected case studies are adaptive reuse conversions throughout New South Wales, chosen among the over 20,000 heritage listed buildings in NSW because they represent *different types of use* and *illustrate the guidelines work in practice* (NSW Department of Planning and RAIA, 2008) plus a pilot study of the GPO Melbourne. The GPO Melbourne was adaptively reused into a retail centre and also considered as one of Melbourne CBD's premier boutique shopping destinations. The following NSW case studies are:

1. Small scale industrial building converted to four-unit residential apartments in Egan Street, Newtown;
2. Conversion of the Grand Babworth House to high-end apartments in Darling Point;
3. Rural agricultural building into a tourist information and function centre in Tocal;
4. Local church and church hall into residential in Glebe;
5. Conversion of the Bushells building, an inner city industrial site into offices in the Rocks;
6. Defence buildings into mixed use development which include the Sydney Harbour Federation Trust Offices in Georges Heights;
7. Commercial building into art gallery in Broken Hill;
8. Conversion of the Mint Coining Factory to the Historic Houses Trust head office and library in Sydney;
9. Railway workshops into health and wellness centre in Newcastle;
10. Conversion of the George Patterson warehouse to a hotel complex in Sydney;
11. Heritage-led urban regeneration, revitalisation of Prince Henry Hospital, a government health facility into mixed use development of residential, commercial and health facilities in Little Bay.

As recipient of numerous Australian awards for heritage and sustainability, the Prince Henry redevelopment project [22] shown in Figures 3 & 4 is presented in this research paper since it contributes to a sustainable future by providing a model for redevelopment of similar heritage and environmentally sensitive areas in Australia. The Prince Henry site has been used by Aborigines for thousands of years and was formerly a dilapidated hospital site for quarantine of infectious diseases. The revitalization of the site balances the old and new developments while keeping 80% of the site in public ownership. Over 90% of demolition materials were reused and buildings comply with energy efficiency principles while the whole redevelopment is based primarily on environmentally sustainable design principles. The Prince Henry master plan starts with the premise of conservation and enhancement. Its principles derive from analysis and evaluation of the physical and cultural framework of the site and surrounding environment. They address ecological sustainability, urban design, heritage, amenity and accessibility. Noteworthy also to mention is that the Prince Henry redevelopment won the President's Award from the Urban Development Institute of Australia in 2009, which was the highest accolade within the UDIA awards program both state-wide and nationally.

Fig. 3: Prince Henry Master Planned Development

Fig. 4: Adaptively-reused Prince Henry Hospital

From the case studies, some of the possible design criteria have been identified. A preliminary unweighted list of design criteria was prepared based on interviews with the architectural team and a survey of relevant documentation. In identifying the list of factors, a semi-structured interview questionnaire with the following themes was prepared:

1. History of the project: a brief background of the project from its existing use to its newly adaptive use or building function; what major decisions/ events that lead to its reuse; major considerations before undertaking the project; latent conditions;
2. Design and technical aspects: impediments encountered during the design process, how modern and green design features (if any) were incorporated or blended to the existing facilities; structural and utility challenges; legal and building code considerations;
3. Design process: design principles and criteria applied or implemented; design consultations conducted with stakeholders; adaptive reuse strategies identified or applied; critical factors that affected the success of adaptive reuse projects.

These discovered design criteria have been linked to the seven factors of obsolescence (physical, economic, functional, technological, social, legal and political) upon which the ARP model is based and illustrate that this connection is possible. The initial set of design criteria, informed by the relevant literature on existing and recent design strategies that pertains to the adaptation of heritage buildings together with other building adaptation and sustainable design concepts/guidelines, are presented in Table 1.

Table 1: Building Adaptive Reuse Design Criteria from Relevant Research Study

Category	Criterion	Relevant Research Study
Long Life (Physical)	Structural Integrity	[23-27]; [10]; [14]
	Material Durability	[4]; [28]; [26]; [10]
	Workmanship	[26]
	Maintainability	[28-30]; [26]; [10]
	Design Complexity	[23-24]; [31];
	Prevailing Climate	[32]
	Foundation	[4]; [26]
Location (Economic)	Population Density	[8]
	Market Proximity	[34-35]
	Transport Infrastructure	[4]; [28]; [36]
	Site Access	[4]; [28]; [36]
	Exposure	[31]; [34-35]
	Planning Constraints	[8]
	Plot Size	[34]; [36]
Loose Fit (Functional)	Flexibility	[4]; [24]; [28-30]; [41]; [36-38];[8]; [10]
	Disassembly	[24]; [30]; [37]
	Spatial flow	[25]; [29]; [39]

Table 1: Building Adaptive Reuse Design Criteria from Relevant Research Study

Category	**Criterion**	**Relevant Research Study**
Loose Fit (Functional)	Convertibility	[24]
	Atria	[40]
	Structural Grid	[23-24]; [41-42]
	Service Ducts and Corridors	[23-24]; [28]; [42]
Low Energy (Technological)	Orientation	[4]; [10]; [28]
	Glazing	[10]; [43]; [47]
	Insulation and Shading	[26]; [10]; [43]; [48]
	Natural Lighting	[25-26]; [10]; [43-44]; [46]; [52]
	Natural Ventilation	[46-47]; [10]; [43-44]; [32]; [52]; [26]
	Building Management Systems	[23-24]; [28]; [43-44]; [18]
	Solar Access	[32]; [10]; [43-47]
Sense of Place (Social)	Image/ Identity	[52]; [6-7]; [50]
	Aesthetics	[28]; [43]
	Landscape/ Townscape	[25]; [52-54]; [46]
	History/ Authenticity	[6-7]; [52]; [28]; [50]; [53]
	Amenity	[31]; [54]; [35]
	Human Scale	[23-24]; [34]
	Neighbourhood	[55]; [31]; [6]
Quality Standard (Legal)	Standard of Finish	[26]; [52]; [44]
	Fire Protection	[25]; [10]; [52]
	Indoor Environmental Quality	[47]; [28]
	Occupational Health and Safety	[10]; [28]; [52]; [47]
	Security	[10]; [28]; [52]; [26]
	Comfort	[26]; [28]; [56]
	Disability Access	[52]; [10]
	Energy Rating	[52]; [10]
	Acoustics	[26]; [10]

Context (Political)	Adjacent Buildings	[25]
	Ecological Footprint	[8]; [18]; [15]; [4]; [56]; [9]
	Conservation	[7]; [53]
	Community Interest/ participation	[8]; [55]; [31]
	Urban Masterplan	[32]; [10]; [36]
	Zoning	[47]; [10]; [32]; [36]; [34]
	Ownership	[55]

As the research progresses, this initial list will be evaluated to determine the weighted value of its associated and corresponding design elements (Stage 2). The set of design criteria reflect the obsolescence categories: Physical (Long Life); Economic (Location); Functional (Loose Fit); Technological (Low Energy); Social (Sense of Place); Legal (Quality Standard) and Political (Context). An example of this framework is shown in Figure 5.

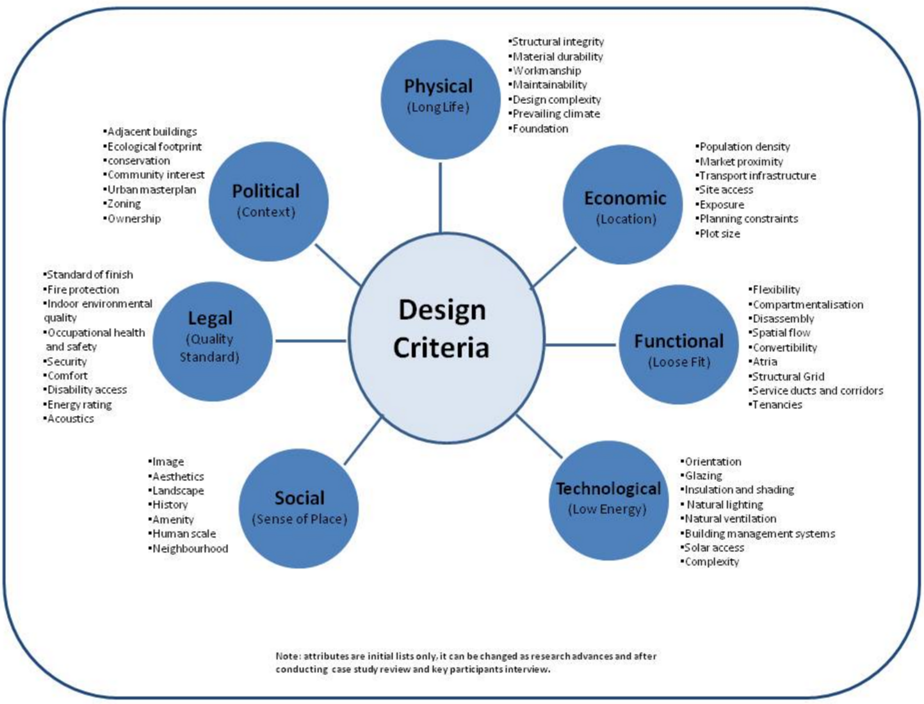


Fig. 5: Proposed adaptSTAR Model

The design criteria will serve as the foundation for the evaluation of new designs using a scale of numerical scores from significant to not significant. An example of how this model will function is demonstrated in Figure 6 using the Physical (Long life) category as an illustration. The relevant design elements with its conditions may comprise:

1. Structural integrity - pertains to the structural design of the building with strength to cater for different future building uses and loading scenarios.
2. Material durability - the materials used for the building play a crucial role in the durability of the building asset; the more durable materials are used, the longer is the building's lifespan.
3. Workmanship - pertains to the quality of craftsmanship applied to the building's structure and finishes.
4. Maintainability - this element addresses the issues enhancing building performance over its lifespan, where maintainability attributes are defined as the capability of a building to conserve operational resources.
5. Design complexity - this element consists of various geometries associated with the design and innovation of the building.
6. Prevailing climate - this element addresses designing for changing climatic conditions that determine appropriate solutions for warm or cold temperature areas.
7. Foundation - this element allows for potential vertical expansion of the building and the stability of the structure in relation to issues such as differential settlement and substrata movement.

Given the base assumption that the Physical category has a value of 14.29%, its corresponding design elements may have different values but must sum to 14.29%. For instance, the structural integrity and foundation may each have a weight of 20%, while the prevailing climate and design complexity may each be valued at 15%, and the rest of the elements may be scored at 10% each of 14.29 (see Figure 6).

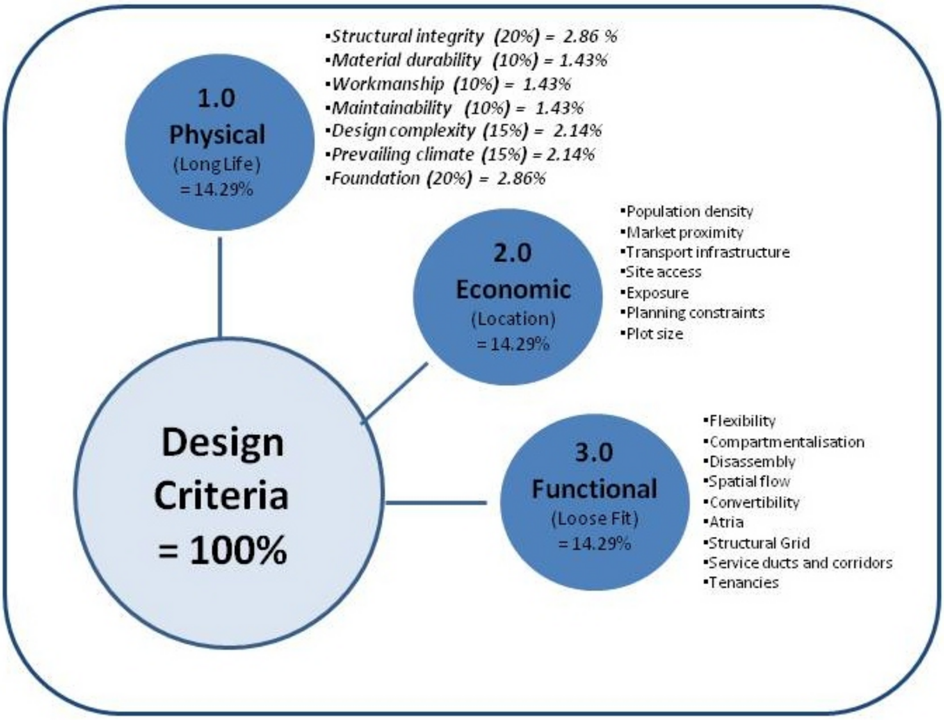


Fig. 6: Proposed adaptSTAR Model: Sample Application

The performance of any new design therefore is scored against these weighted criteria and used to assemble a total score or star rating for the future building. The higher this score, the better it is at addressing future adaptive reuse opportunities.

Conclusion and Further Research

Our contemporary architecture will be tomorrow's heritage and will contribute to another layer of the inherent character of cities. Conservation is more than heritage protection - it is an approach that recognizes the change of uses that may occur in the built environment while maintaining its intrinsic heritage values. The reuse of existing buildings is a more sustainable strategy than demolition and replacement. However, when designing new buildings it is important to be concerned on maximising the adaptive reuse potential of buildings later in their lives to help mitigate the effects of a changing climate. Moreover, designers should fully understand the context of the existing built environment and consider the needs of new buildings through appropriate design technologies.

The final development of the new design rating tool known as the adaptSTAR model is underway. This research paper has initially identified important design criteria needed for the sustainability and future adaptive reuse of new buildings. The research methodology outlined in this research study will assist in the reliability and validity of the new design rating tool. The outcome of this research and the application of the adaptSTAR model will be useful in the adaptive reuse of existing built environment as well as incorporation of adaptive reuse strategies for future buildings. In addition, this research will help promote the development of low to no carbon built environments.

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About the Authors

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Sheila is currently studying as a full time PhD Candidate. Her research focus is on urban conservation, heritage conservation, adaptive reuse, urban planning and architecture related topics. Prior to her PhD studies, she studied at the United Nations University, Tokyo, Japan (2003) and at the Asian Institute of Technology, Bangkok, Thailand (1998). Sheila has been a licensed and practicing Architect and Urban Planner in the Philippines since 1993. She managed to be active in both industry and academic fields; she has worked as an Assistant Professor at the University of the Philippines-School of Urban and Regional Planning (1999) and also worked as a planning consultant in Cebu City, Philippines. She has worked as a Research Fellow under the Japan Government REDP-B grant in 1998 and as the United Nations Centre for Human Settlements-National Consultant to Cebu City for the Agenda 21+5 in 2000.

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Following graduation from his PhD in 1995, Dr. Langston has worked as a full-time academic (teaching + research) at the University of Technology Sydney (Associate Professor), Deakin University (Professor) and now at Bond University (Professor). He is currently Associate Director (Research) in the Institute of Sustainable Development and Architecture. Prior to that, he was Associate Dean Research in the Faculty of Business, Technology and Sustainable Development for over two years. He was awarded the Bond University Vice-Chancellor's Quality Award for Research Excellence in 2010, equivalent to University Researcher of the Year. Dr. Langston has made significant contributions to scholarship in the building and construction industry over the last ten years. This includes four books published by Butterworth-Heinemann and Elsevier, several book chapters, guidelines for life cycle costing practice in Australia, the production of three software packages used by professional firms and educational institutions, and numerous conference presentations both in Australia and overseas. He has published in well-recognized refereed journals and has served on several editorial boards, including as editor-in-chief. His PhD developed a new approach to the calculation of time equivalence in discounting via the inclusion of affordability considerations linked to predicted changes in living standards.

Prof. Jim Smith
Dr. Jim Smith brings a wealth of practical expertise and academic knowledge to his role as Professor of Urban Development. After qualifying as a quantity surveyor with the Royal Institution of Chartered Surveyors (RICS) in 1971, he worked extensively in private practice and local government in the UK and Australia. His academic career encompasses teaching positions in Singapore and Hong Kong, as well as the University of Melbourne and Deakin University where he was instrumental in developing the Bachelor of Building and the Graduate Diploma in Quantity Surveying. Dr. Smith has maintained close ties with industry as a specialist cost advisor in private practice and to state government departments. Smith

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The second publication medium is through the book imprint On Climate, publishing cutting edge books in print and electronic formats. Publication proposals and manuscript submissions are welcome.

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